Laminated Root Rot

A Guide for Reducing and Preventing Losses in Oregon and Washington Forests

Forest Service

Pacific Northwest Region

1985

Laminated Root Rot

A Guide for Reducing and Preventing Losses in Oregon and Washington Forests

James S. Hadfield
USDA-Forest Service
Pacific Northwest Region
Forest Pest Management
Portland, Oregon

Preface

Laminated root rot is the most serious disease found in Oregon and Washington forests. Hundreds of thousands of acres are affected and trees representing millions of board feet of timber are killed by the disease. This guide for reducing and preventing losses caused by laminated root rot has been prepared specifically for foresters and others concerned with controlling this disease in Oregon and Washington. It describes how to recognize the disease, how it spreads and damages host trees, and how to reduce losses.

Resource productivity of infested sites can be greatly expanded by controlling laminated root rot. The information presented has been compiled from several sources and represents more than 50 years of research and observations by forest pathologists in the Pacific Northwest. Information developed since the first edition of this publication was issued in 1977 has been added to this second edition.

The Problem

Laminated root rot, caused by *Phellinus weirii* (Murr.) Gilbertson, is one of the most damaging and difficult diseases to control in Pacific Northwest conifer forests. It is widespread, occurring throughout the range of Douglas-fir in Oregon and Washington. Douglas-fir is the most important host, but nearly all conifers appear to be susceptible to attack to some degree. In the Douglas-fir forests of western Oregon and Washington, laminated root rot has been estimated to cause an annual loss of 32 million cubic feet of timber. At least 5 percent of the forested area is thought to be infested. Trees of all ages and sizes are susceptible to infection, but damage is most obvious in stands 20 to 150 years old.

Laminated root rot can be considered a disease of the site. Because of its persistence and spread from one rotation to the next, the fungus has potential for greatly reducing site productivity. Projections of forest productivity in the Pacific Northwest Douglas-fir region must account for the effects of laminated root rot; otherwise, the projections will be unrealistic.

Damage can be reduced by appropriate treatments; conversely, damage can be increased by some actions.

Recognizing the Disease

Recognition of the signs and symptoms of laminated root rot is essential to reducing losses. If foresters do not recognize the disease, they may not apply appropriate treatments.

Laminated root rot centers appear as patches of dead and dying trees. West of the crest of the Cascade Range the infection centers are usually smaller than one acre; east of the Cascades, they frequently encompass more than one acre.

In some stands, laminated root rot may have a diffuse distribution that is difficult to detect. In these cases, the disease does not cause distinct patches of tree killing but, rather, affects groups of one to several trees throughout the area of infestation.

The appearance of laminated root rot centers varies with stand age and tree size. Seedlings only 1 or 2 years old are susceptible to infection and may be killed, but the disease usually does not begin to kill trees until they reach 10 to 15 years of age. In sapling stands, the disease often appears to affect scattered individual trees rather than groups of trees. Infected saplings usually die standing because they do not have enough crown weight to topple in spite of the decayed roots; also, they are killed quicker than larger trees.

The disease creates understocked, roughly circular openings in pole-size and larger stands. At later stages of the disease, disease pockets may coalesce to form large, irregular-shaped openings several acres in size. Patches of windthrown and leaning trees oriented in several directions are good indicators of laminated root rot (Figure 1). In contrast, in blowdown areas where root rot is not involved, the downed trees are usually oriented in the same general direction. When infected trees fall, the decayed roots are often broken off close to the root collar, forming "root balls" (Figure 2). The root balls are especially helpful for diagnosing laminated root rot because

Figure 1. Root disease center caused by *Phellinus weirii* in a pole-size Douglas-fir stand in western Washington. Note numerous windthrown trees.

few other root diseases cause this symptom. Callus tissue may form on the living ends of large roots that have been decayed for some time before the trees are windthrown. Brush and herbaceous plants frequently thrive in older infection centers in response to the increased amount of sunlight penetrating the stand canopy.

Crown symptoms of infected trees are variable and may not become noticeable until 50 percent or more of the root system has been destroyed. Root-rotted trees may be windthrown before crown symptoms appear. Reduced terminal growth is usually the first crown symptom. The crowns become thin, ragged, and yellow in the final stages of tree decline. A "distress" crop of abundant, smaller-than-normal cones may be produced. These crown symptoms are not always indicators of laminated root rot. They can also be produced by other root diseases, root-feeding insects, or animal damage.

The disease symptoms may not be apparent in infected overmature stands of Douglas-fir, especially if trees have not been killed for many years. The only evidence of laminated root rot may be windthrow that happened several decades ago. When the infected large trees are cut, stained and decayed wood will be seen in the stumps.

Laminated root rot can be most readily identified by the characteristic appearance of the decayed wood. The early stage of wood decay is reddish-brown to brown, appearing as streaks or broad bands on longitudinal sections of the butt and main roots and as circular, crescent, or irregular-shaped areas on cross sections (Figure 3). The stained wood fades after a few weeks once the wood has been exposed. Typical advanced decay can be found on the exposed ends of broken

Figure 2. Uprooted Douglas-firs exhibiting "root balls."

Figure 3. Cross-section of an infected Douglas-fir stump showing the characteristic red-brown, crescent-shaped areas of incipient decay caused by *P. weirii*.

Figure 4. Advanced laminated decay caused by *P. weirii*. Note the separation of the annual rings and small pits in the wood.

roots or by cutting into the bases of standing dead trees. The decayed wood is laminated and pitted. The wood separates by annual rings. The light yellow-brown sheets of decayed wood contain numerous oval pits about ½-millimeter wide and 1 millimeter long (Figure 4). Thin velvety layers or sparse tufts of reddish-brown mycelium can usually be found growing between the laminated sheets of decayed wood. With a hand lens, this mycelium, which is called setal hyphae, looks like reddish-brown, wiry whiskers (Figure 5). Thin cinnamon-brown mycelial crusts often form on roots with advanced decay. In the final stages of decay, the wood becomes a loose, stringy mass that disintegrates, leaving hollows in the butts of affected trees.

Laminated root rot may infect and kill small trees with small-diameter roots without causing laminated decay.

The disease can be identified on living trees by exposing roots near the root collar and looking for gray-white mycelium on the surface of roots. It forms a continuous sheath around infected roots. The reddish-brown setal hyphae can be seen mixed through the mycelium (Figure 6). Unlike common molds, which sometimes grow on the surface of tree roots, the mycelium of *P. weirii* penetrates the bark tissues and cannot be easily rubbed off. Brown, crust-like mycelium can often be found in the crotches of roots.

The fruiting bodies of *P. weirii* are brown crusts with tiny pores that usually form on the lower sides of windthrown trees and exposed roots in late summer and early fall. They vary in length from a few inches to several feet. The fruiting bodies, lying flat against the bark, are inconspicuous and are not produced frequently enough to be considered useful for diagnosis.

Aerial photography has been used to accurately detect laminated root rot centers in mountain hemlock stands near the crest of the Cascades. The centers appear as unstocked irregular-shaped openings with white margins (Figure 7). Aerial photography has been a reliable method for detecting laminated root rot in stands of Douglas-fir less than 30 years old in western Oregon and Washington but has not been useful in older stands.

Figure 5. Setal hyphae within *P. weirii* decayed wood look like reddish-brown whiskers.

Figure 6. *P. weirii* mycelium on the surface of the bark at the base of a small Douglas-fir.

Figure 7. Aerial photo (Scale 1:8000) showing openings caused by laminated root rot in a mountain hemlock stand near the crest of the Cascades.

Damage

Laminated root rot is a tree killer and contributor to windthrow. In addition to the harvestable volume killed directly, potential future volume is lost when the disease occupies a site and prevents reestablishment of a thrifty stand. *P. weirii* usually does not extend more than 5 to 8 feet above ground in living trees, so butt rot losses are much less important than tree killing. Trees less than 10 years old are usually killed soon after their roots come into contact with inoculum. Older trees may sustain significant growth loss for up to 30 years after infection before succumbing. Douglas-firs that become infected after they are 40 years old are unlikely to be killed by the disease before they would normally be harvested. Indirectly, the disease contributes to losses caused by bark beetles which are attracted to trees weakened by root rot or recently windthrown. The trees weakened by root rot may serve as brood trees for bark beetles that can spread to nearby healthy trees.

Damage increases with stand age as the disease spreads and infection centers become more numerous. A 10-percent incidence of disease in a 20-year-old stand is more threatening than the same incidence in a 60-year-old stand. The number of trees affected doubles about every 15 years after the disease first becomes apparent.

Potential for damage is greatest where susceptible tree species are growing in the presence of large volumes of buried infected wood from the previous stand. In these situations, the disease will gradually spread and by the end of the rotation will greatly reduce the volume that could have been grown on the site. The disease will be at least as destructive in the current rotation as it was in the previous rotation if infested sites are regenerated with highly susceptible tree species.

Disease Development

P. weirii can survive in large roots and stumps in the soil for 50 years or more after the trees have been cut or killed. Laminated root rot begins to cause damage in a young stand when live roots of susceptible trees contact *P. weirii* mycelium on diseased roots and stumps of the previous stand. After the infection is established on live roots, the fungus spreads along the root system, penetrating the bark, killing and decaying the roots. *P. weirii* must grow on wood; it cannot grow in soil. The fungus spreads to the root collar, around it, and out the other roots. Root contacts provide an extensive disease pathway within the stands (Figure 8). The disease pockets are estimated to expand about 1 foot per year.

Laminated root rot creates understocked openings in stands by killing the trees. As these openings increase in size and age, a "doughnut" effect may become evident. Several feet behind the active edge of openings caused by laminated root rot, living trees may be absent. Closer to the center of openings, seedlings may become reestablished. When the roots of susceptible seedlings contact diseased roots, they also become infected and the disease cycle is repeated (Figure 9). Trees tolerant or immune to attack may become established in the openings; if so, they will be considerably smaller than susceptible trees on the edges of openings.

Figure 8. Disease spread. The disease spreads when healthy roots of susceptible species contact infected roots.

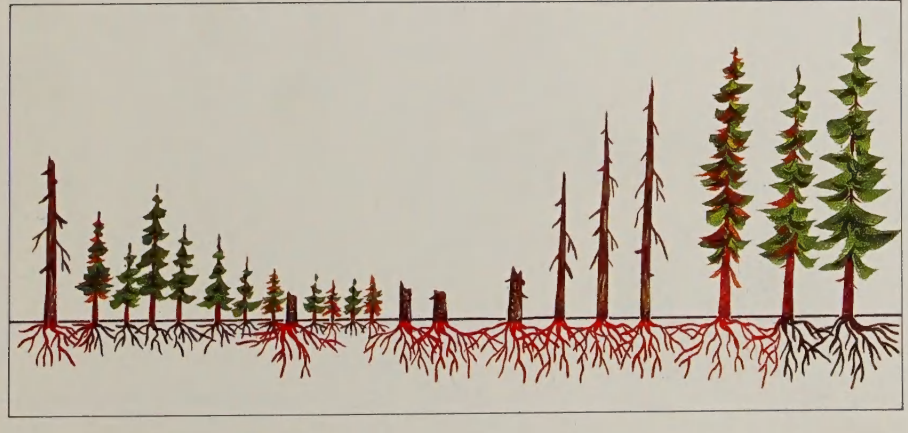

Figure 9. Doughnut effect. Trees become reestablished in the older portions of the infection centers. If they are susceptible, they will become infected when their roots contact the infected roots of the former stand of trees.

In stands of poles and larger timber, the area occupied by infected roots extends beyond that indicated by crown symptoms. Trees with hidden infection may not display any crown symptoms until 50 percent or more of the root system has been killed. Only about half the number of infected trees within a disease center will have crown symptoms. Crown symptoms may not be noticeable in poles and larger timber until 10 or more years after the initial infection. Tree death will usually occur 5 to 10 years after symptoms develop. Susceptible trees that are within 15 feet of one killed by laminated root rot are usually infected. As the distance from the closest killed tree increases, the percentage of infected trees decreases. At 50 feet, infection from the same source is rare (Figure 10).

Planting susceptible species on untreated, infested sites will increase the amount of inoculum, causing damage to increase with each rotation. The seriousness of the damage will increase in direct proportion to stocking density and promptness of planting after harvesting since these factors influence the time required for healthy roots to contact inoculum (Figure 11).

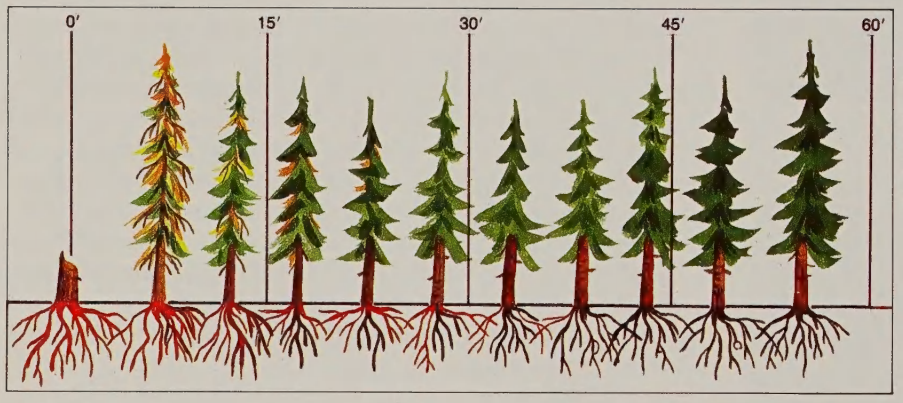

Figure 10. Hidden infection. Infected roots can be present on trees that do not show crown symptoms. All susceptible trees within 15 feet or one or two normal tree spacings of a dead tree, are probably infected but, at 50 feet from the same source, infection is rare.

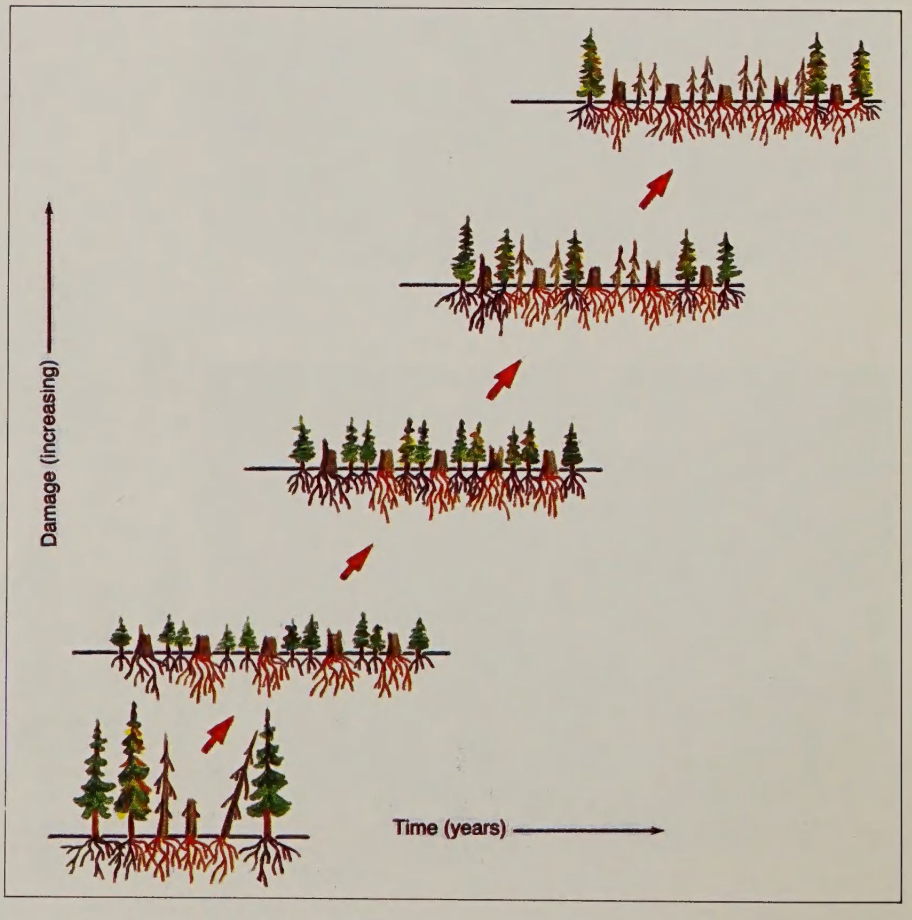

Figure 11. Planting susceptible species on untreated, infested sites will result in an increase of damage with each rotation.

Host Susceptibility

Douglas-fir, mountain hemlock, grand fir, white fir, and Pacific silver fir are the most susceptible species and the most seriously damaged by laminated root rot. If these species are planted on untreated, infested sites, they cannot be raised to maturity without serious losses. Although Douglas-firs are highly susceptible to infection, some trees are able to survive with the disease for many years by confining the decay to a small number of roots and interiors of butts. These trees will have almost no crown symptoms, even though their butts may be hollow.

Western hemlock, noble fir, California red fir, subalpine fir, Sitka spruce, Engelmann spruce, and western larch are intermediate in susceptibility to laminated root rot. They can be infected when they grow in close association with the most susceptible species. The intermediately susceptible species experience more butt decay than tree killing. They are seldom severely damaged if they are not growing in association with the most susceptible species. If these species of intermediate susceptibility are planted on infested sites formerly occupied by the most susceptible species, some losses will occur.

Lodgepole pine, western white pine, and sugar pine may be infected when they are growing in association with the most susceptible species. They appear to be tolerant of the disease and are seldom seriously damaged. They are rarely infected unless they are growing in association with the most susceptible species.

Ponderosa pine, western redcedar, incense cedar, Port-Orford-cedar, and Alaska yellow cedar are rarely damaged by laminated root rot in Oregon and Washington. *P. weirii* is an important cause of butt rot of western redcedar in the northern Rocky Mountains, but windthrow and tree killing are rare. Mycelial development on cedar roots is very limited.

All hardwoods are immune to the disease.

Table 1. Susceptibility of Pacific Northwest Tree Species to Laminated Root Rot

Susceptible	
Pacific silver fir	*Abies amabilis*
White fir	*Abies concolor*
Grand fir	*Abies grandis*
Douglas-fir	*Pseudotsuga menziesii*
Mountain hemlock	*Tsuga mertensiana*
Intermediately susceptible	
Subalpine fir	*Abies lasiocarpa*
California red fir	*Abies magnifica*
Noble fir	*Abies procera*
Western larch	*Larix occidentalis*
Engelmann spruce	*Picea engelmannii*
Sitka spruce	*Picea sitchensis*
Western hemlock	*Tsuga heterophylla*
Tolerant	
Lodgepole pine	*Pinus contorta*
Western white pine	*Pinus monticola*
Sugar pine	*Pinus lambertiana*
Resistant	
Alaska cedar	*Chamaecyparis nootkatensis*
Incense cedar	*Libocedrus decurrens*
Ponderosa pine	*Pinus ponderosa*
Western redcedar	*Thuja plicata*
Port-Orford-cedar	*Chamaecyparis lawsoniana*
Immune (hardwoods)	
Bigleaf maple	*Acer macrophyllum*
Red alder	*Alnus rubra*
Pacific madrone	*Arbutus menziesii*
Tanoak	*Lithocarpus densiflorus*
Cottonwood	*Populus* spp.
Poplar, aspen	*Populus* spp.
Oak	*Quercus* spp.

Management Recommendations

Recommendations for reducing laminated root rot losses must take into consideration distribution and severity of the disease, stand age, tree size and species, and site. Many small disease centers scattered through a stand are a more serious deterrent to sustained timber productivity than a few large centers because they present more infested perimeter from which the fungus can spread outward. Either planting with disease-resistant conifers or hardwoods, or stump and root removal must be considered seriously where the disease is well distributed. Planting untreated sites with susceptible species will result in serious losses. Disease distribution is often nonuniform; therefore, it may be possible to partition stands according to disease severity and to treat each compartment separately. In stands with only a few small infection centers, the most appropriate decision in some cases may be to ignore the disease.

What Will Not Work

Applications of nitrogen fertilizers in amounts as high as 2,000 pounds of available nitrogen per acre have failed to inhibit growth of the fungus on roots; however, they may shorten the time *P. weirii* can survive in roots.

Broadcasting burning, even with hot fires, will not create temperatures high enough to kill the fungus in buried roots.

Partial cutting or clearcutting will not control the disease because the fungus persists for many years in large roots and stumps.

Breeding Douglas-fir with resistance to laminated root rot offers little promise at this time because highly resistant trees have not been found.

Wide spacing is not a practical control because spacing would have to be so wide that stocking would be unacceptably low and wood quality would be reduced. Furthermore, natural regeneration would probably fill in the unstocked areas and create numerous root contacts to spread the disease.

What Will Work

The most economical and practical solution in many cases is to reforest diseased sites with tree species that are not susceptible to serious damage by laminated root rot. Fortunately, most sites in Oregon and Washington are capable of producing good growth on several tree species.

Table 1 lists the susceptibility of Oregon's and Washington's commercially important tree species to laminated root rot.

Susceptible Group — These species should not be planted within 50 feet of a disease pocket. If they are, losses to disease will be at least as serious as in the previous stand.

Intermediate Group — These species may become infected, but usually they do not suffer serious damage unless they are growing in association with susceptible species. If pure stands of the intermediate species are planted on a site containing infected roots of susceptible species, some losses probably will occur, but it should be possible to grow them through a normal rotation without serious losses. Planting of intermediate species may allow the fungus to persist on a site since their roots can become infected. Their roots may also provide a disease pathway to adjacent susceptible species.

West of the Cascades, Sitka spruce and western hemlock could be planted in disease pockets instead of Douglas-fir. In higher elevations of the Cascades, noble fir, California red fir, Engelmann spruce and subalpine fir should be favored over the more susceptible Pacific silver fir, Douglas-fir and mountain hemlock. East of the Cascades, Engelmann spruce and western larch should be selected instead of grand fir, white fir, or Douglas-fir.

Tolerant Group — Lodgepole pine, sugar pine, and western white pine can become infected if they are growing in close association with infected susceptible species. Even though they may become infected, they usually are not seriously damaged. Where they are silviculturally adapted to an infested site, the tolerant species should receive preference over susceptible and intermediate species.

Resistant Group — Conifers in the resistant group are rarely damaged by laminated root rot. If pure stands of resistant conifers are maintained in disease pockets, *P. weirii* will gradually die out over a normal rotation. West of the Cascades, western redcedar and incense cedar can be safely grown in laminated root rot centers where Douglas-fir has been damaged. East of the Cascades, ponderosa pine and incense cedar should be used.

Immune Group — Hardwoods are immune to infection by *P. weirii.* If they are adapted to the site, they could be grown instead of susceptible conifers. Hardwoods would probably have to be grown for a minimum of 40 years on a site formerly occupied by large infected trees before it would be safe to replant with susceptible conifers. It would take about that long for most of the *P. weirii* to die out of most of the infected roots.

Mixed plantings of hardwoods and susceptible conifers in infested sites will not protect the susceptible conifers because the conifer roots will contact the infected roots from the previous stand before *P. weirii* has died out. Pure stands of hardwoods established in infection centers will prevent the disease from spreading to subsequent crops of conifers on those sites and to adjacent uninfested areas.

Mechanical removal of infected stumps and large roots will be effective in reducing the root rot hazard to future stands. The effectiveness of this approach depends on the volume of infected wood left in the soil after treatment. Tractors equipped with soil-ripping teeth that can penetrate up to 3 feet into the soil will bring large roots to the surface. A splitter attachment allows easier handling of large stumps. Well-decayed roots and smaller roots will be broken by the soil rippers and may not be brought to the surface. The broken roots will decompose faster than intact roots and should not present a serious source of inoculum. It is not necessary to remove the roots and stumps, brought to the surface, from the planting area because the fungus cannot grow through soil to infect roots. After a thorough stump and root removal treatment, it should be possible to raise a crop of susceptible species, such as Douglas-fir, to rotation age without serious losses. Some losses may still occur since the fungus might survive in occasional broken root pieces and infect healthy roots contacting them; however, such losses would be small.

Potential losses can be avoided by harvesting infected stands early. This practice will not control the disease unless follow-up treatments such as root and stump removal, or reforestation with less susceptible species, are applied to the site. Early harvest of infected stands is beneficial from the standpoint that recently killed trees and living infected trees will be salvaged before they become too deteriorated for wood product conversion, and smaller stump size will likely mean shorter survival time for the fungus.

The following management recommendations are presented by tree size classes for saplings, poles and small sawtimber, large sawtimber, and recently harvested stands. In all cases, the treatments described are intended for stands in which species most susceptible to laminated root rot are, or recently have been, present. Foresters can take action to reduce losses from laminated root rot at each stage of stand development.

Treatments for Sapling Stands

1. Examine stands when the average tree height reaches 10 to 15 feet, or diameter is 1 to 2 inches at breast height. Information is most efficiently gathered during routine examinations prior to precommercial thinning. Symptoms of laminated root rot begin to appear in stands 10 to 15 years of age; however, younger trees may also be killed, some within a few years of planting. At this stage of stand development, only individual scattered trees may be visibly affected; whereas in older infected stands, groups of trees will be affected. Stumps from the previous stand should be examined for laminated root rot. If laminated root rot is present, map the concentration of diseased trees and stumps. Record whether the infested areas are few or numerous, scattered or concentrated.

2. Record the data in a permanent record where they can be readily retrieved.

3. Select for cutting all trees with symptoms and neighboring nonsymptomatic trees whose roots could provide a disease pathway to healthy susceptible trees (Figure 12). Tolerant, resistant, and immune tree species next to affected trees would not have to be cut. Stocking density

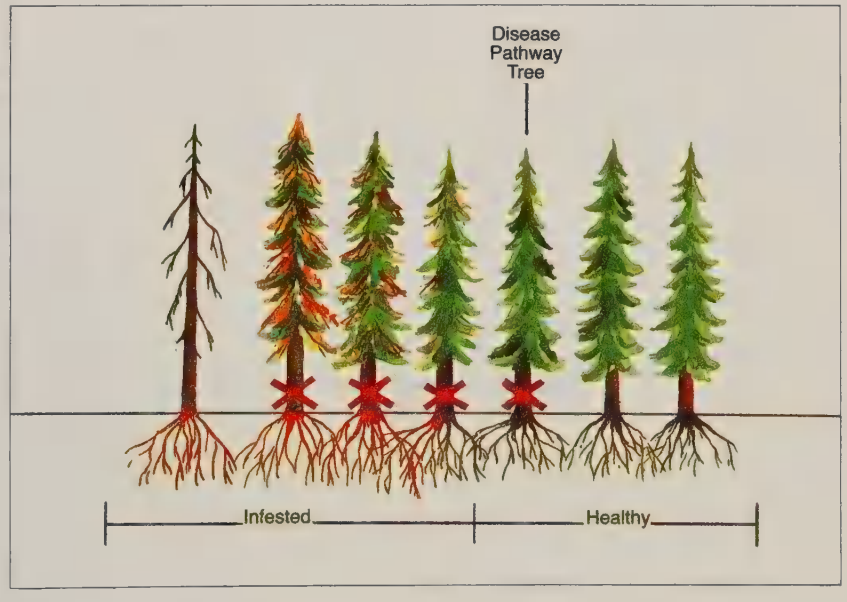

Figure 12. Disease tree thinning. Remove nonsymptomatic host trees within two normal tree spacings of symptomatic trees to stop spread of *P. weirii* in roots. Favor tolerant or resistant conifers or hardwoods for crop trees within 50 feet of visibly infected trees or stumps.

will influence the number of nonsymptomatic trees that should be cut to break the disease pathway to healthy trees. In most sapling stands, the nonsymptomatic pathway trees to be cut will be within a zone that extends two normal tree spacings beyond trees that have sparse, yellow foliage. The purpose of the treatment is to disrupt movement of *P. weirii* mycelium along root systems by killing the roots of the nonsymptomatic pathway trees. The fungus does not spread on dead roots. This treatment will be effective only if tree markers or thinners are skilled in detecting symptoms of laminated root rot and can locate the periphery of disease centers. The treatment will not always stop the spread of laminated root rot in sapling stands. However, if the thinning is done by people trained in disease recognition, spread should be greatly reduced. Stand openings created by this treatment should be reforested with less susceptible tree species. Always try to favor tolerant or resistant conifers or hardwoods when thinning near disease centers in sapling stands.

4. If removal of all symptomatic trees and nonsymptomatic pathway trees would create a stand of unacceptable stocking, consideration should be given to destroying the stand immediately and reforesting the site with less susceptible tree species or removing inoculum and planting with any tree species.

5. Silvicultural treatments intended to maximize growth rates of saplings, such as control of competing vegetation, precommercial thinning, and fertilization will not make trees exposed to large amounts of inoculum more resistant to infection by *P. weirii.* On the other hand, there is no evidence these treatments increase spread of the disease. It would be appropriate to integrate these growth stimulating treatments with the removal of symptomatic and adjacent nonsymptomatic trees described above. This approach would enable the trees to reach harvestable size in the shortest time. If disease losses are unacceptable at that time, the stand could either be harvested and the site reforested with a less susceptible tree species, or stumps and roots treated, and the site planted with any tree species.

6. Doing nothing is not a desirable disease management alternative in severely infected stands of saplings on average to good sites. Either regenerate the stands or apply growth-stimulating treatments to shorten the time needed for the trees to obtain harvestable size.

Treatments for Pole and Small Sawtimber Stands

1. Examine stands for laminated root rot and map the location of disease centers. Record the information in a permanent record where it can be readily retrieved.

2. In stands where the disease is not severe, the healthy parts of the stand can be thinned as usual, but disease pockets should be identified and treated differently. Three alternative treatments could be applied to the pockets.

   a. Cut all dead and dying trees in the disease pocket plus all host trees within two normal tree spacings of symptomatic trees (Figure 12). Keep as crop trees tolerant or resistant conifers and valuable hardwoods. Reforest the resultant opening with tolerant, resistant, or immune tree species.

   b. Do not cut any trees within 50 feet of the edge of disease pockets (Figure 13). This will not stop or delay spread of the disease but will result in less windthrow than if the entire stand is thinned because closed crown canopies provide some protection of individual trees from wind. Infected trees with green crowns have a high probability of being windthrown if surrounding trees are cut.

   c. Under most circumstances, windthrow of harvestable trees is not desirable because the sapwood quickly deteriorates and bark beetle populations may build to outbreak levels in them. However, windthrow of live, merchantable-size trees with laminated root rot can be beneficial because the volume of inoculum in the soil will be reduced as roots are pulled out. *P. weirii* will die

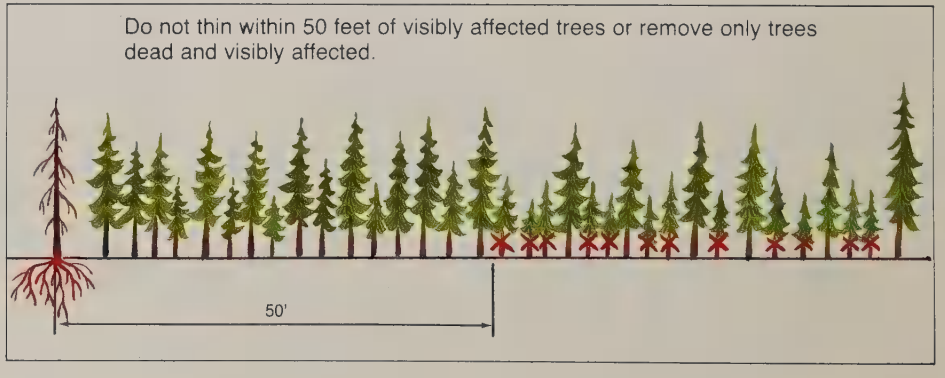

Figure 13. Do not thin within 50 feet of infection centers in pole and small sawtimber stands.

in roots exposed to air. Seldom would all infected trees in a disease center be windthrown, so disease control will almost always be incomplete.

In places where it is possible to salvage small volumes of windthrown trees yearly, thinning of diseased stands can avoid some disease losses. Remove symptomatic trees and nonsymptomatic host trees within one normal tree spacing and thin the rest of the stand to desired stocking levels. The thinned, infected portions of stands should be examined yearly for about 5 years after thinning to detect windthrown and standing dead trees for salvage. It is important to salvage windthrown trees yearly to prevent outbreaks of bark beetles, especially Douglas-fir beetles, from developing in them.

Disease distribution must be considered when deciding whether to thin. Foresters should assume that in pole and small sawlog-size stands most susceptible species within 20 feet of a visibly affected tree will have decayed roots and will be windthrown if the stand is thinned.

3. Do not thin severely infected stands with numerous, well-distributed disease pockets. If the trees with hidden infection are kept as crop trees, they will soon be windthrown because their decayed roots will not support them.

4. Clearcut infected stands earlier than normally planned when the net volume increment is below the minimum acceptable amount. Treat the clearcut site as described in the section on "Treatments After Final Harvests."

Treatments for Large Sawtimber Stands

1. Map the disease centers during sale layout. It is often easier to locate disease centers at this time than after the stands have been harvested. Identify disease pockets in the stands by marking affected trees at the root collar with a tag or suitable identifying symbol that will remain visible after logging and slash burning. Record information on disease distribution in a permanent record for easy retrieval.

2. Harvest the infected stands if the net volume increment is below the minimum acceptable amount. Timber fallers can help in controlling the disease if they are instructed to mark stumps with stain or laminated decay. Infected stump tops should be marked by making two shallow parallel chainsaw cuts perpendicular to the undercut (Figure 14). Where terrain, size of trees, and other conditions permit, reduce the volume of infected root wood in the soil of infection centers by pushing out stumps or pushing over whole trees. Stump-splitting attachments for tractors may be helpful for treating large stumps. Avoid burying large pieces of infected wood during logging. Treat the harvest site as described in the next section.

Treatment After Final Harvest

This is the most effective time to actually control laminated root rot so that it will not be a problem in future stands to be grown on the site.

1. Mark disease pockets for machine operators or tree planters by locating infected stumps. Infected stumps can be identified by the characteristic reddish-brown stain or laminated decay in the stump top. Timber fallers should mark stumps as previously described. Ideally, stumps

Figure 14. Douglas-fir stump with *P. weirii*-caused stain marked with a chainsaw to aid in locating treatment boundaries.

should be examined for stained wood within 2 days after they are cut because the stain fades when exposed to light, and resin and dirt on the stump top obscure the stain.

2. Where terrain and economics allow, remove all infected stumps and major roots in the infection centers, plus those within 50 feet. Replant the area with any species adapted to the site.

3. If stumps and roots are not removed, plant disease pockets and a 50-foot-wide surrounding band with resistant or tolerant conifers or with hardwoods that are adapted to the site (Figure 15). Intermediate species could also be planted. Intermediate species can become infected and allow the fungus to persist on the site, but disease losses should not be serious. If resistant conifers or hardwoods are planted and susceptible species are not allowed to become established, *P. weirii* will gradually die out.

4. Do not plant disease pockets with susceptible species unless the pockets are so small and few or difficult to treat that the cost of treating them differently from the remaining portion of the stand would exceed the value of damage expected from the disease.

5. Examine the plantings at frequent intervals to monitor success of treatment.

Treatments for Intensively Used Sites

Trees with laminated root rot pose a serious hazard to permanent structures and people. Infected trees are prone to windthrow.

1. Consult forest pathologists when any root rot is suspected or has been identified in campgrounds, picnic sites, or near buildings that could be struck if the trees fell. Recommendations for or against the removal of suspect trees can be made after a thorough evaluation of the site.

2. Do not locate new developments within or adjacent to areas affected by root rot.

3. Schedule and conduct annual evaluations of hazard trees in high-use areas such as campgrounds.

These recommendations proposed for stands in various stages of development were designed to be used as general guides for foresters. Foresters must recognize that the prescription for a particular stand or management unit will depend on an evaluation of disease potential, management intensity, and goals.

Additional Information

Additional information and training on laminated root rot is available on request from the following agencies:

USDA — Forest Service
Forest Pest Management
P.O. Box 3623
Portland, Oregon 97208

Oregon State Department of Forestry
2600 State Street
Salem, Oregon 97310

Washington State Department
of Natural Resources
Division of Private Forestry
202 Public Lands Building, QW-21
Olympia, Washington 98504

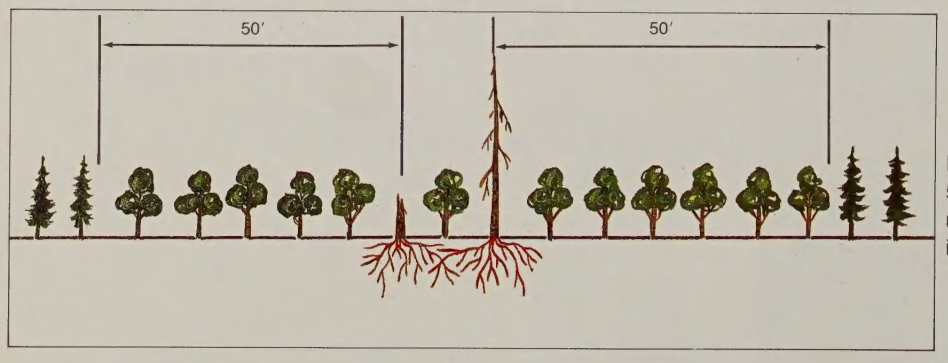

Figure 15. Do not plant susceptible conifers within 50 feet of infection centers. Plant only tolerant or resistant conifers or hardwoods within 50 feet of infection centers.

References

Bloomberg, W. J. and G. W. Wallis
1979. Comparison of indicator variables for estimating growth reduction associated with *Phellinus weirii* root rot in Douglas-fir plantations. Can. J. For. Res. 9:76-81.

Bloomberg, W. J., P. M. Cumberbirch, and G. W. Wallis
1980. A ground survey method for estimating loss caused by *Phellinus weirii* root rot. II. Survey procedures and data analysis. BC-R-4, 44p. Can. For. Serv./Pac. For. Res. Ctr., Victoria, British Columbia.

Bloomberg, W. J. and G. Reynolds
1981. Factors affecting transfer and spread of *Phellinus weirii* mycelium in roots of second-growth Douglas-fir. Can. J. For. Res. 12:424-427.

Childs, T. W.
1970. Laminated root rot of Douglas-fir in western Oregon and Washington. USDA For. Serv. Res. Pap. PNW 102, 27 p. Pac. NW For. & Range Exp. Sta., Portland, Oregon.

Filip, G. M. and C. L. Schmitt
1979. Susceptibility of native conifers to laminated root rot east of the Cascade Range in Oregon and Washington. For. Sci. 25:261-265.

Filip, G. M. and D. J. Goheen
1982. Hazards of root disease in Pacific Northwest recreation sites. J. of For. 80(3):163-164.

Filip, G. M. and D. J. Goheen
1984. Root diseases cause severe mortality in white and grand fir stands of the Pacific Northwest. For. Sci. 30:138-142.

Hansen, E. M.
1975. *Phellinus (Poria) weirii* root rot in Douglas-fir-alder stands 10-17 years old. USDA For. Serv. Res. Note PNW 250, 5 p. Pac. NW For. and Range Exp. Sta., Portland, Oregon.

Hansen, E. M.
1979. Survival of *Phellinus weirii* in Douglas-fir stumps after logging. Can. J. For. Res. 9:484-488.

Johnson, D. W. and J. F. Wear
1975. Detection of *Poria weirii* root rot centers in the Pacific Northwest with aerial photography. Plant Dis. Rep. 59(1):77-81.

Lawson, T. T., A. B. Berg, and E. M. Hansen
1983. Damage from laminated root rot at the Black Rock Forest Management Research Area in western Oregon. Res. Note 75, 7 p., For. Res. Lab, Oregon State Univ., Corvallis, Oregon.

Nelson, E. E.
1971. Invasion of freshly cut Douglas-fir stumps by *Poria weirii.* USDA For. Serv. Res. Note PNW 144, 5 p. Pac. NW For. and Range Exp. Sta., Portland, Oregon.

Nelson, E. E., and T. Hartman
1975. Estimating spread of *Poria weirii* in a high-elevation mixed conifer stand. J. For. 73(3):141-142.

Nelson, E. E.
1980. Laminated root rot damage in a young Douglas-fir stand. USDA For. Res. Note PNW 359, 15 p., Pac. NW For. and Range Exp. Sta., Portland, Oregon.

Nelson, E. E., N. E. Martin, and R. E. Williams
1981. Laminated root rot of western conifers. USDA For. Serv. For Ins. and Dis. Leaf. 159, 6 p.

Thies, W. G.
1983. Determination of growth reduction in Douglas-fir infected by *Phellinus weirii.* For. Sci. 29:305-315.

Thies, W. G.
1984. Laminated root rot: the quest for control. J. of For. 82:345-356.

Tkacz, B. M. and E. M. Hansen
1982. Damage by laminated root rot in two succeeding stands of Douglas-fir. J. of For. 80:788-791.

Wallis, G. W.
1976. *Phellinus (Poria) weirii* root rot. Detection and management proposal in Douglas-fir stands. Can. For. Serv. For. Tech. Rep. 12, 16 p.

Wallis, G. W. and W. J. Bloomberg
1981. Estimating the total extent of *Phellinus weirii* root rot centers using above- and below-ground disease indicators. Can. J. For. Res. 11:827-830.

Wallis, G. W. and Y. J. Lee
1984. Detection of root disease in coastal Douglas-fir stands using large scale 70-mm aerial photography. Can. J. For. Res. 19:523-527.

☆ U.S. GOVERNMENT PRINTING OFFICE:1985—596-837